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1. Introduction

In this study, we delve into MRI data from patients with and without dementia, employing mixed-effects ANOVA to uncover patterns of brain changes and their interactions with intracranial volume factors.

Research Question:

1. Does the structure of the brain change significantly over time in people with dementia compared to people without dementia?
2. How does dementia status influence the estimated total intracranial volume across different visits, and are there significant differences between groups over time?

2. Data Cleaning:

In our study on dementia's impact on brain structure and the influence of intracranial volume, we began with a dataset featuring 16 columns and 294 rows. To focus our analysis, we refined the data to include essential columns: 'Subject ID', 'Group' (nondemented, demented, or converted), 'Visit' (first or second visits), 'M/F' (gender), 'eTIV' (estimated total intracranial volume), and 'nWBV' (normalized whole brain volume). In addition, we found some missing records for "SES" or "MSE" scores in the dataset, but the questions we examined were not related to these records, so they were not cleaned.

3. Exploratory Data Analysis

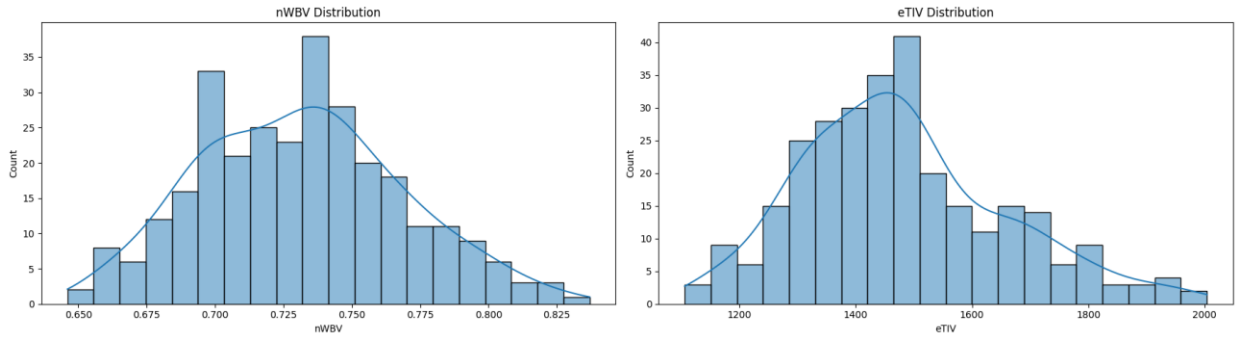

Figure 1 nWBV & eTIV Histogram

The nWBV histogram shows a left-skewed distribution, indicating that while most subjects had values in the middle range, there was a small group of subjects with higher brain volumes. The peaks indicate that the most common nWBV measurements were between 0.73 and 0.75. On the eTIV histogram, we see a more normally distributed pattern, with most subjects' intracranial volumes clustered between 1400 and 1600 cubic centimeters. The symmetry of this distribution suggests that positively high or extremely low intracranial volumes are not common in this cohort.

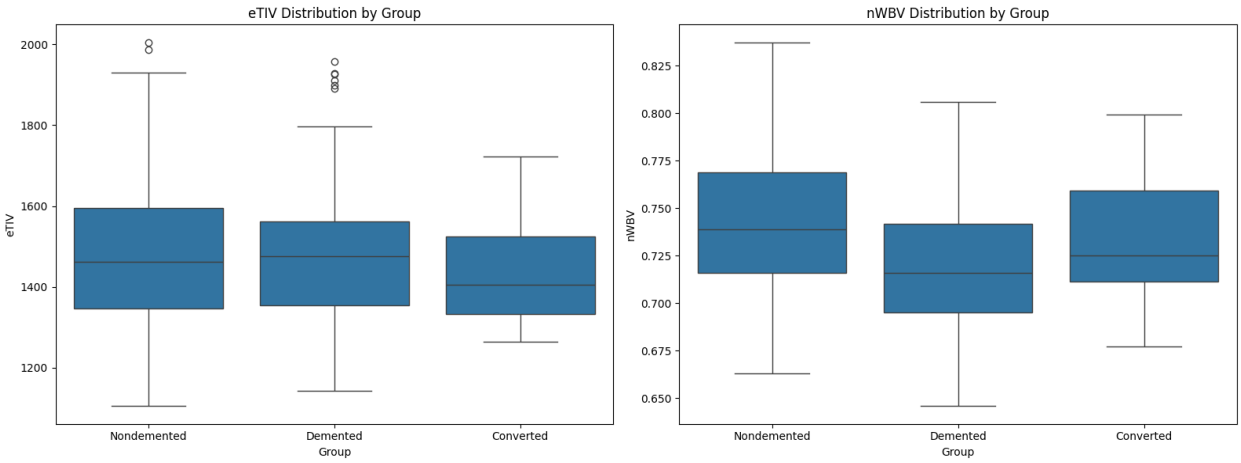

Figure 2: nWBV & eTIV Box Plot

The box plots illustrate the distributions of eTIV and nWBV across three dementia status groups: Nondemented, Demented, and Converted. In terms of eTIV, all groups showed similar interquartile ranges, but the median eTIV in the dementia group appeared to be slightly lower compared with the nondemented and converted groups. In the nWBV plots, the median nWBV was higher in the non-dementia group and lowest in the converted group compared to the dementia and converted groups.

4. Mixed-Effect ANOVA

4.1 Research Question 1: Does the structure of the brain change significantly over time in people with dementia compared to people without dementia?

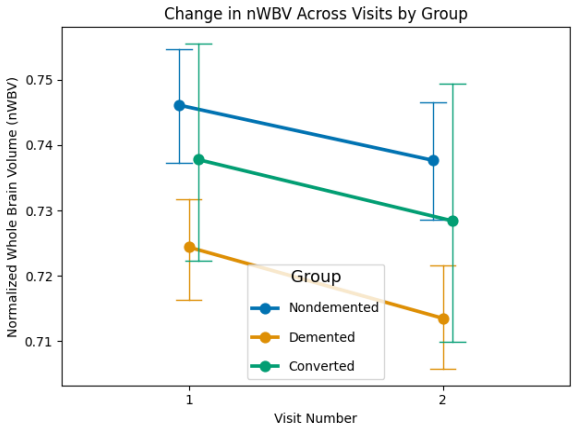

Figure 3:Pointplot of change in nWBV Across Visits by Group

The point plot illustrates the changes in nWBV across two visits, segmented by dementia status groups: Nondemented, Demented, and Converted. The data indicates a decrease in nWBV for all groups from Visit 1 to Visit 2. The Demented group shows the most substantial reduction in nWBV, which could signify a more significant progression of brain atrophy compared to the Nondemented group, which exhibits a more modest decline. The Converted group also displays a noticeable decrease, with notably larger error bars, suggesting greater variability within this group. The plot supports the notion that brain structure, as quantified by nWBV, changes over time in dementia patients, with these changes being more pronounced in those with dementia compared to those without.

Source	SS	DF1	DF2	MS	F-value	P-value	np2
Group	0.034	2	141	0.017	6.712	0.002	0.087

Visit	0.007	1	141	0.007	94.251	<0.001	0.401
Interaction	0.000	2	141	0.000	1.534	0.219	0.021

Table 1: nBWV ANOVA Summary

ANOVA Summary & Post Hoc Tests Analysis:

Mixed ANOVA found significant differences in nWBV among dementia groups (F=6.712, p=0.002), showing varying nWBV levels. Time had a highly significant effect on nWBV (F=94.251, p<0.001), indicating a sharp decline over visits. The interaction between group and time was not significant (F=1.534, p=0.219), suggesting a consistent nWBV reduction trajectory across groups. Post hoc analysis confirmed significant nWBV change from Visit 1 to Visit 2 (T=9.672, p<0.0001), reinforcing that nWBV decreases significantly over time.

Test for assumption:

The Shapiro-Wilk test for normality of the residuals returned a p-value equal to 5.90e-07, suggesting the data significantly deviates from normality. However, the homogeneity of variances is satisfactory, with Levene's test yielding a p-value of 0.478, indicating no significant variance differences across groups.

4.2 Research Question 2: How does dementia status influence the estimated total intracranial volume across different visits, and are there significant differences between groups over time?

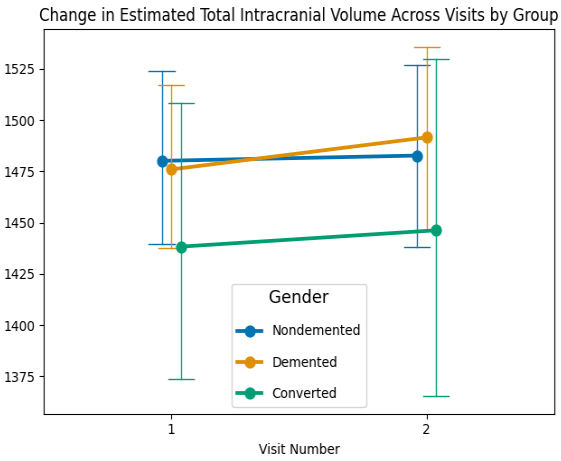

Figure 4:Pointplot of change in eTIV Across Visits by Group

The point plot for eTIV indicates that there are no substantial differences in the estimated total intracranial volume when comparing the Nondemented, Demented, and Converted groups across two visits. Each group's eTIV measurements remain relatively constant from the first to the second visit, suggesting that dementia status does not significantly influence the eTIV within the timeframe of these visits. The error bars, which represent the confidence intervals, show some overlap between the groups at both visits, further supporting the lack of significant differences between the groups over time. The Converted group does exhibit larger variability in eTIV values compared to the other groups, which is noticeable in the wider confidence intervals.

Source	**SS**	**DF1**	**DF2**	**MS**	**F-value**	**P-value**	**np2**
Group	37424.70	2	141	18712.35	0.297	0.743	0.004

Visit	5573.92	1	141	5573.920	9.225	0.003	0.061
Interaction	1004.78	2	141	502.392	0.831	0.438	0.012

Table 2: eTIV ANOVA Summary

ANOVA Summary & Post Hoc Tests Analysis:

Mixed ANOVA showed no significant differences in eTIV between dementia groups (F=0.297, p=0.743), indicating eTIV homogeneity. However, time significantly affected eTIV (F=9.225, p=0.003), showing changes across visits. No significant interaction between group and visit (F=0.831, p=0.438) suggested consistent eTIV change across dementia statuses over time. Post hoc tests revealed within-subject significance from Visit 1 to Visit 2 but no significant differences between groups, indicating dementia status does not affect eTIV changes over time.

Test for assumption:

The Shapiro-Wilk test for normality shows a p-value is 4.25e-23, which strongly indicates that the residuals for the eTIV data do not follow a normal distribution. In contrast, Levene's test for homogeneity of variances has a p-value of 0.6906, suggesting that the variances across the groups are equal and meet the assumption of homogeneity. These results show the violation of the normality assumption while the variance across groups remains consistent.

5. Statistical Power Analysis:

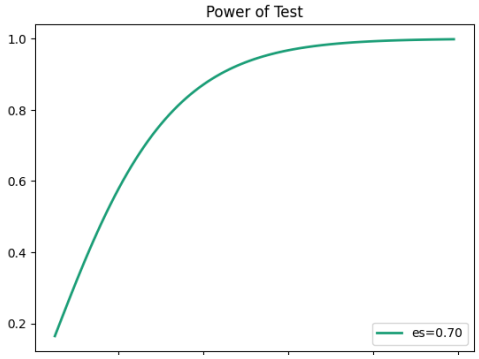

Figure 5: Power Plot for t-test

The power curve graph illustrates how the power of a statistical test increases with the number of observations for an effect size of 0.70. The graph indicates that to achieve the desired power of 0.91, a sample size of between 60 and 80 participants per group is necessary, given an alpha level of 0.05. The actual power achieved with the sample sizes used in this study was 45.451, which is below the target, suggesting that increasing the sample size could be necessary for future studies to detect the effect with higher confidence.

6. Conclusion:

In summary, the study's analysis showed a decrease in normalized whole brain volume over time across all dementia groups, while estimated total intracranial volume stayed consistent. There was no significant interaction between dementia status and time, pointing to a uniform reduction in nWBV regardless of dementia progression. These insights enhance our comprehension of dementia-related changes in brain structure.